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Seino et al.

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(54) **COIL COMPONENT**

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Mar. 4, 2021 (JP) 2021-034789

(51) **Int. Cl.**

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H01F 17/00	(2006.01)
H01F 17/04	(2006.01)
H01F 27/255	(2006.01)
H01F 27/29	(2006.01)
H01F 27/32	(2006.01)

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CPC ***H01F 27/255*** (2013.01); ***H01F 17/0013*** (2013.01); ***H01F 27/292*** (2013.01); ***H01F 27/324*** (2013.01); *H01F 2017/0066* (2013.01)

(58) **Field of Classification Search**
CPC .. H01F 27/255; H01F 17/0013; H01F 27/292; H01F 27/324; H01F 2017/0066; H01F 17/04; H01F 2017/048
See application file for complete search history.

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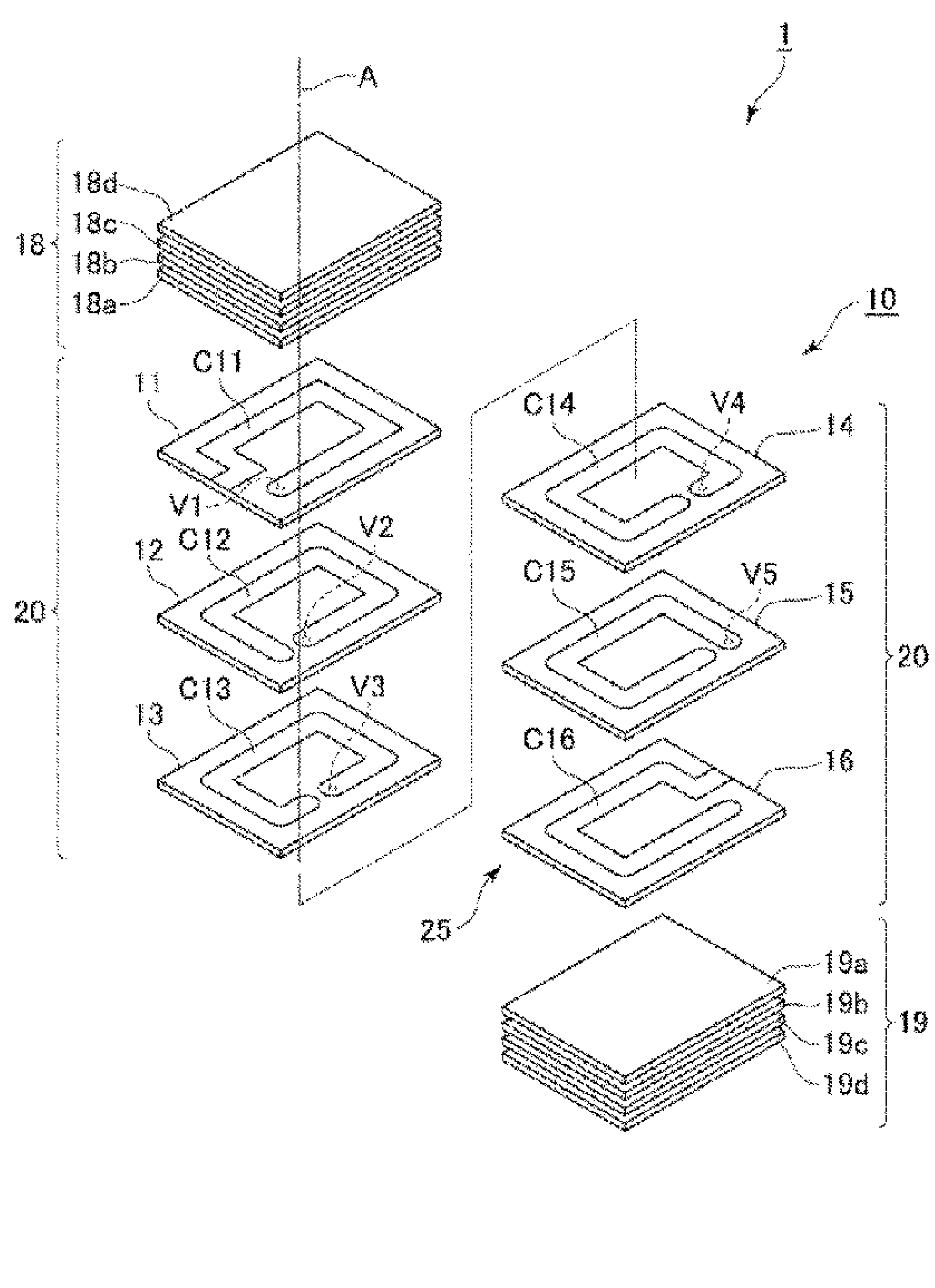
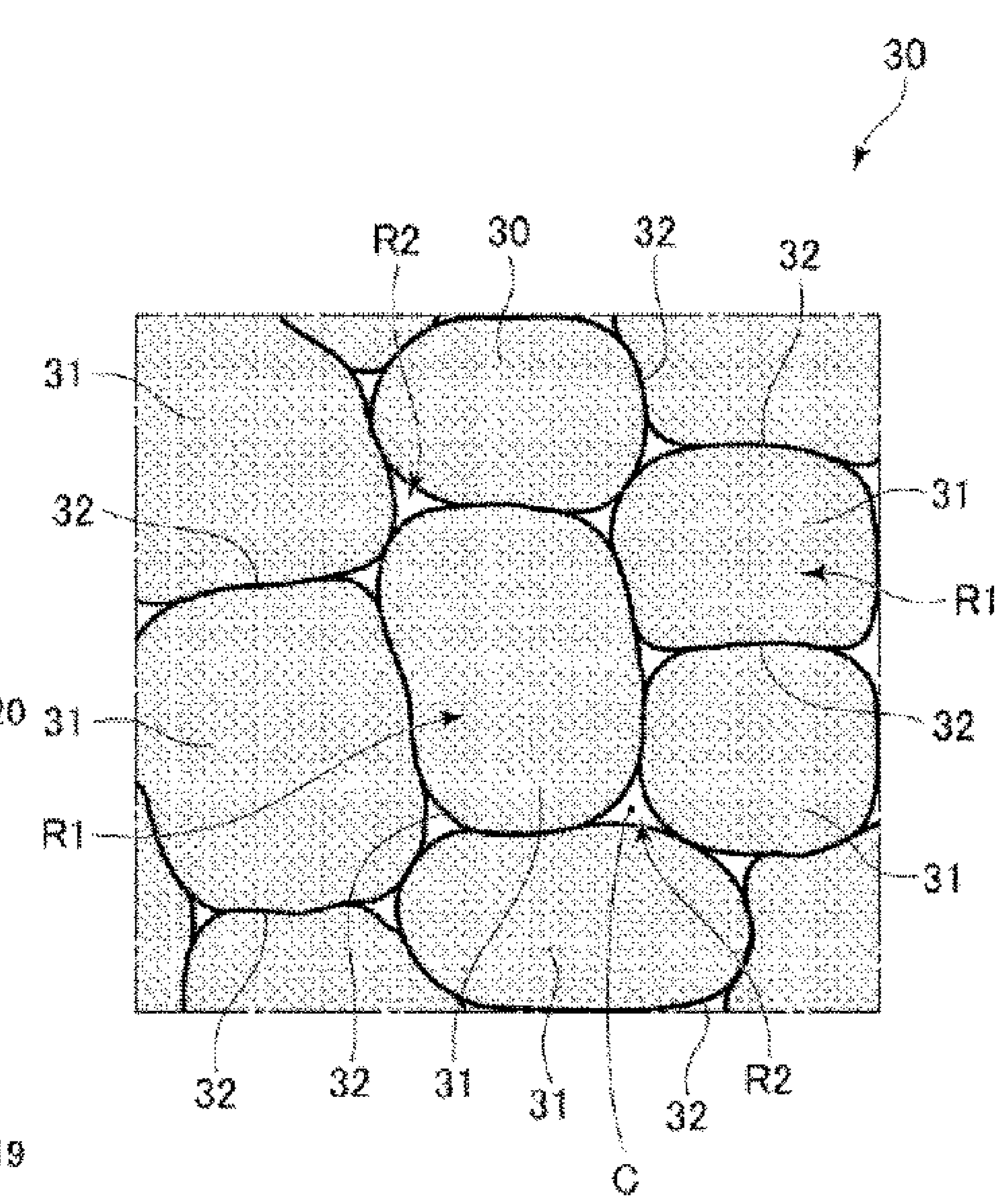
(57) **ABSTRACT**

A coil component includes: a laminated body containing a plurality of metal magnetic particles; and a coil conductor provided in the laminated body so as to contact with the laminated body and wound around a coil axis, wherein the laminated body has an insulating portion including a non-metal magnetic particle region defined by at least three of the plurality of metal magnetic particles in a sectional surface of the laminated body, and wherein in the insulating portion, an atomic percent of Si is highest among those of materials constituting the non-metal magnetic particle region other than oxygen.

16 Claims, 11 Drawing Sheets





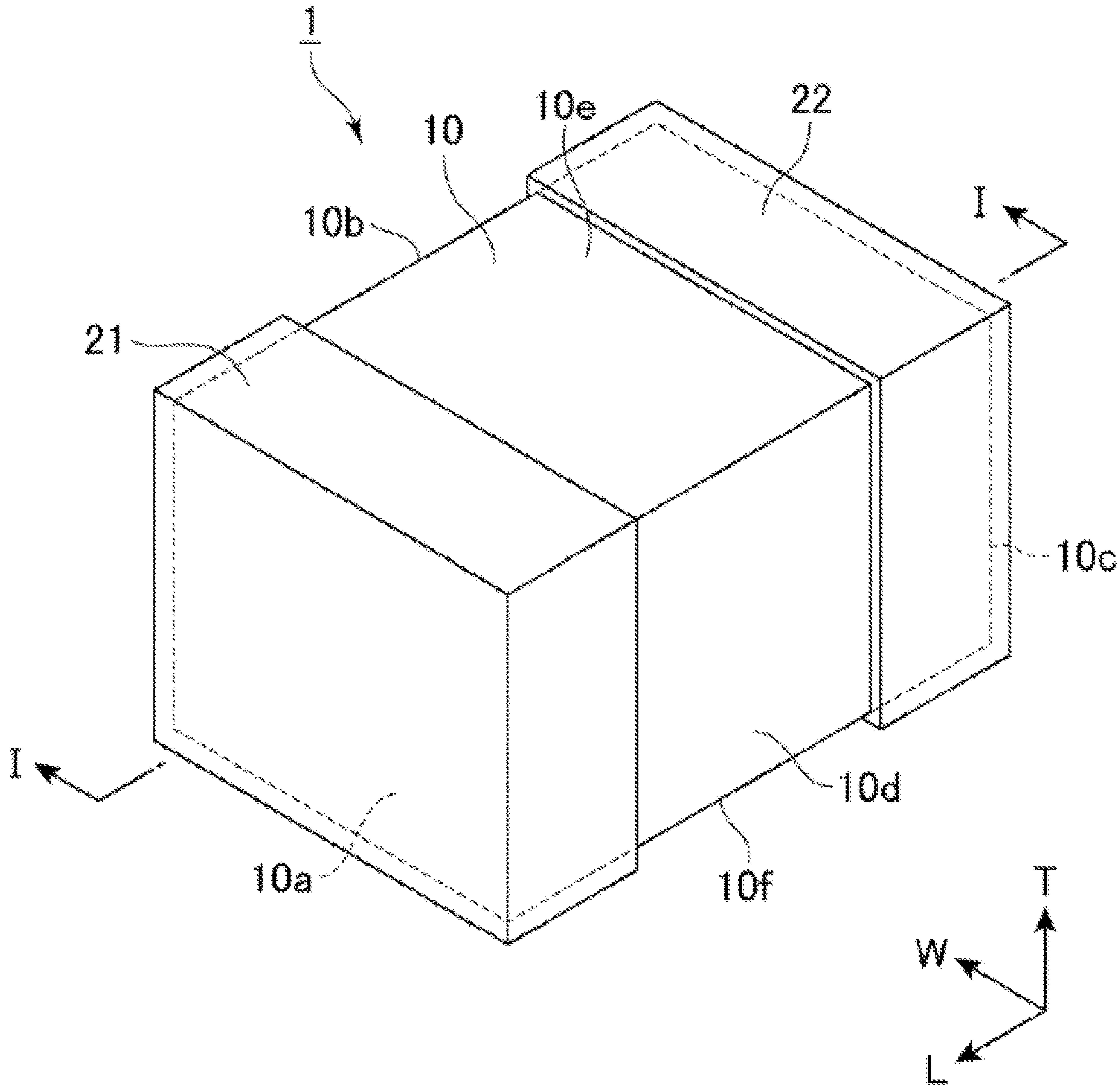
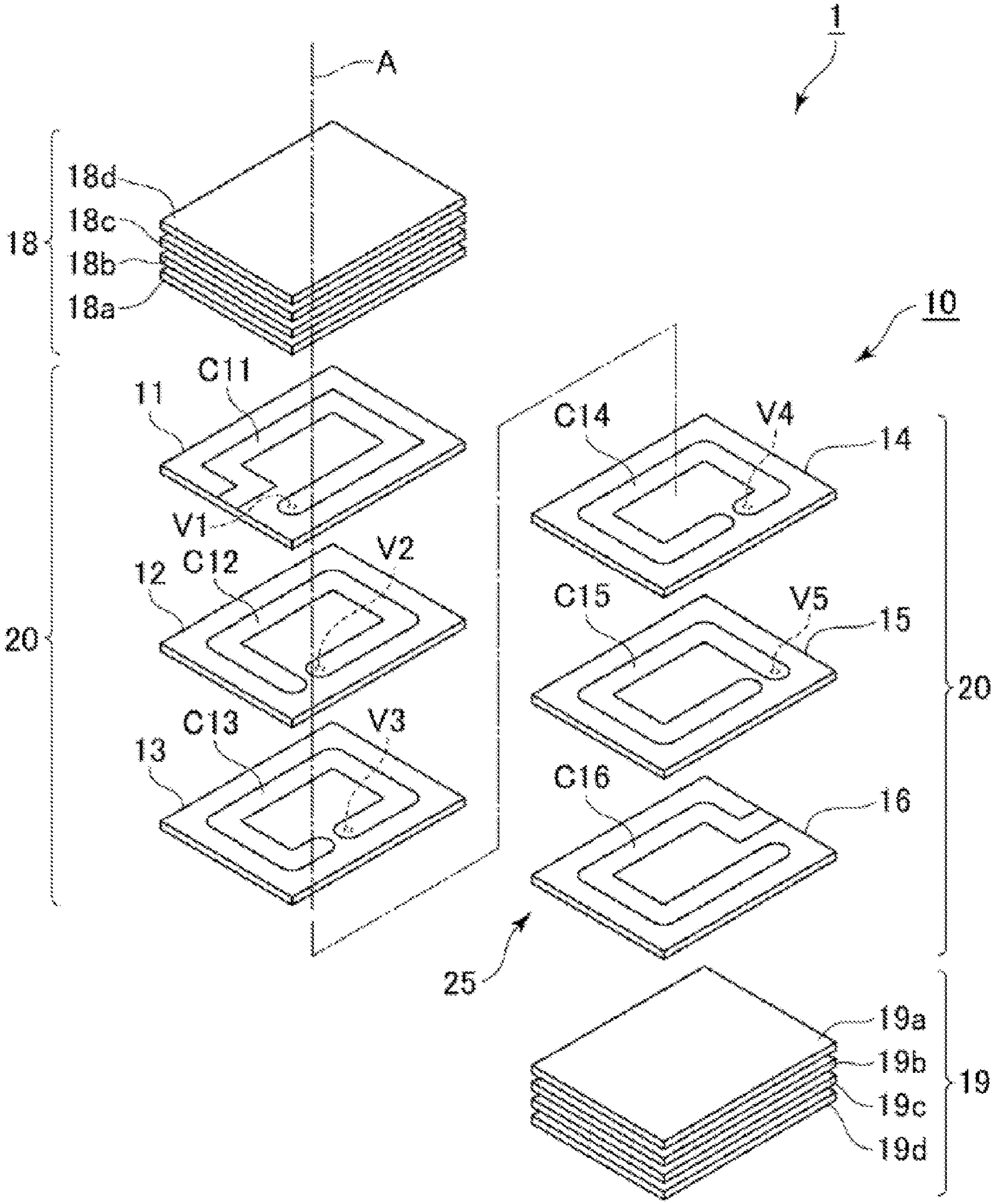


Fig. 1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V3
C14
V4
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C15
V5
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C16
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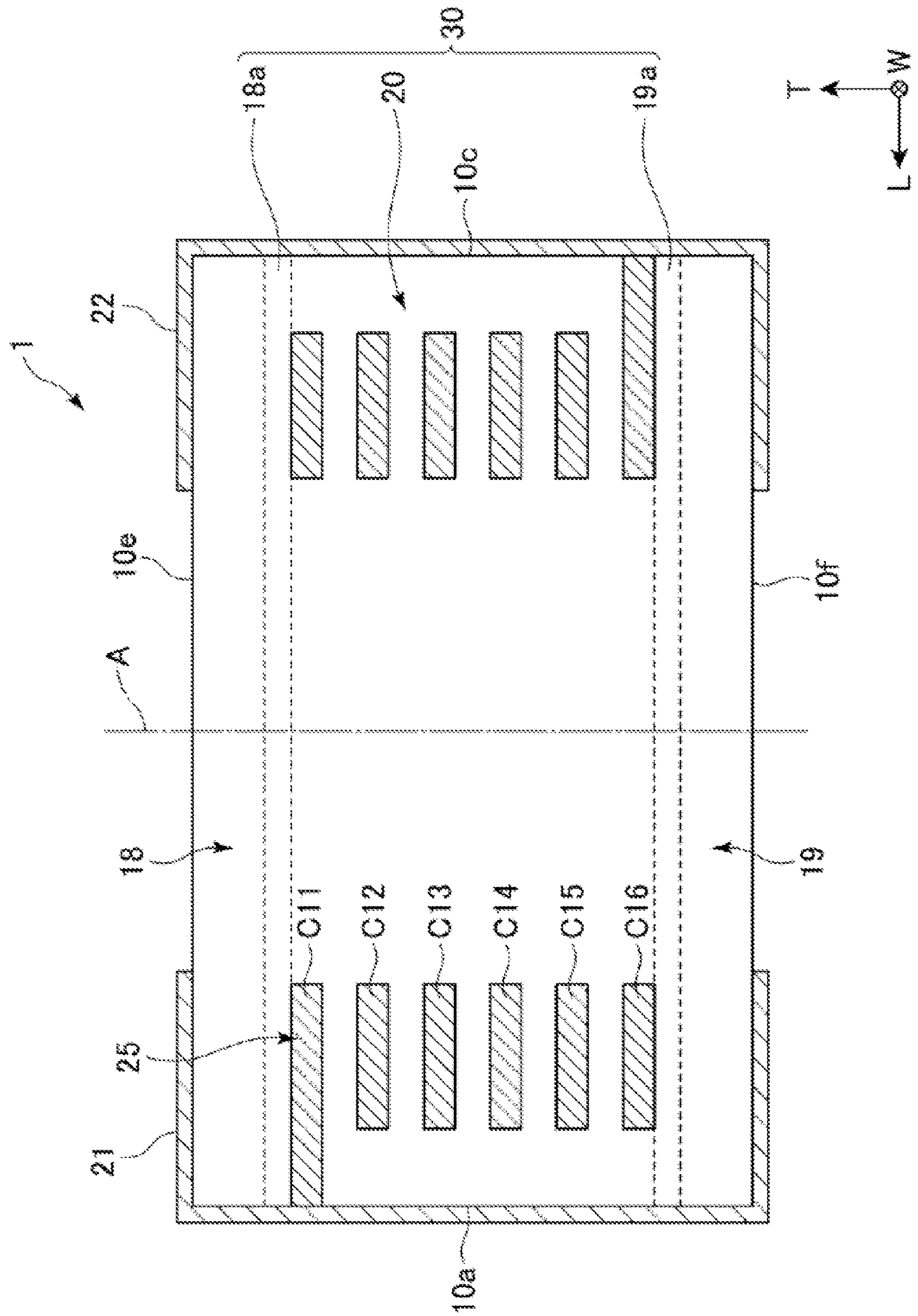
19c
19d
19

Fig. 2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C16
25
21
10a

Fig. 3

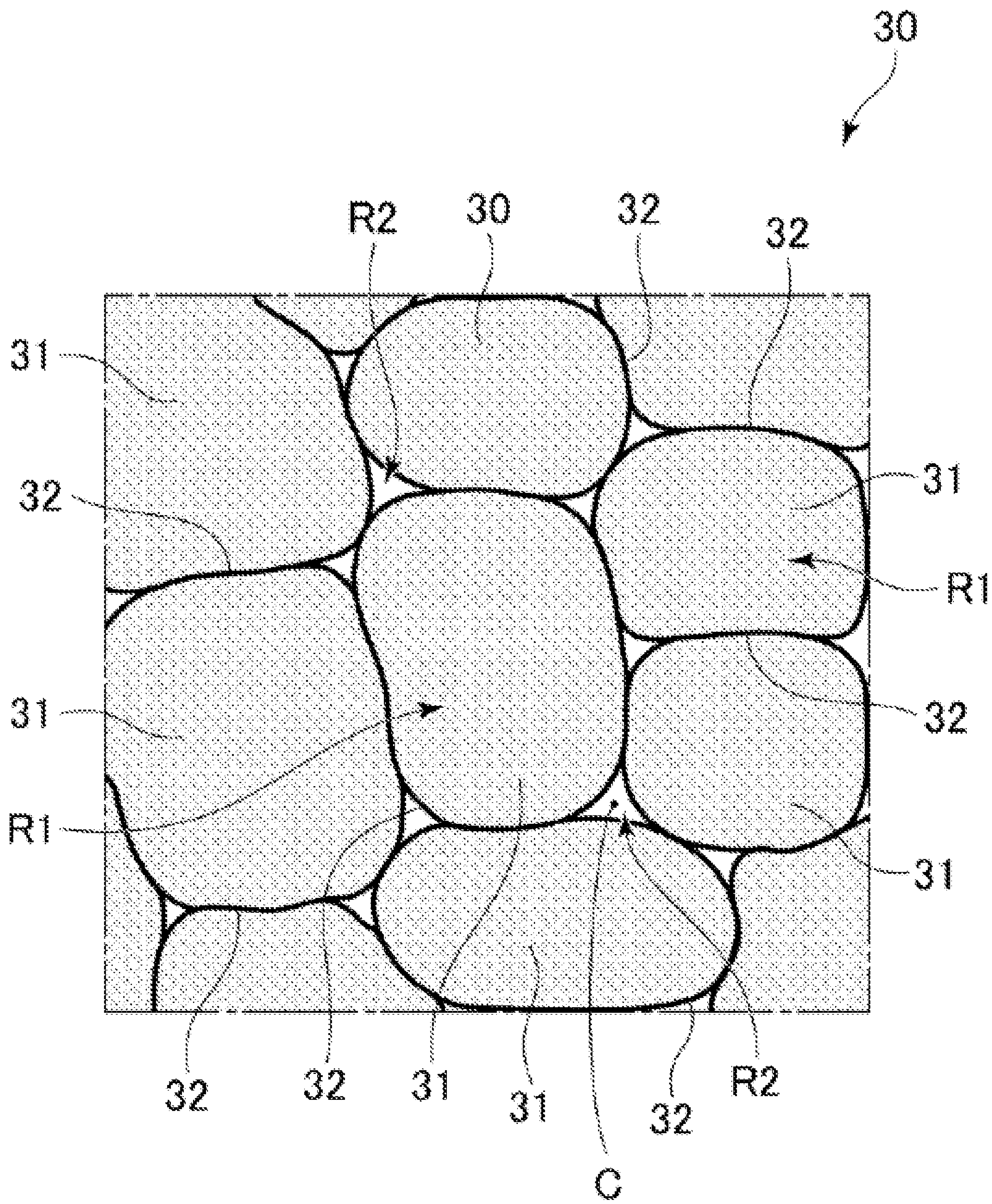
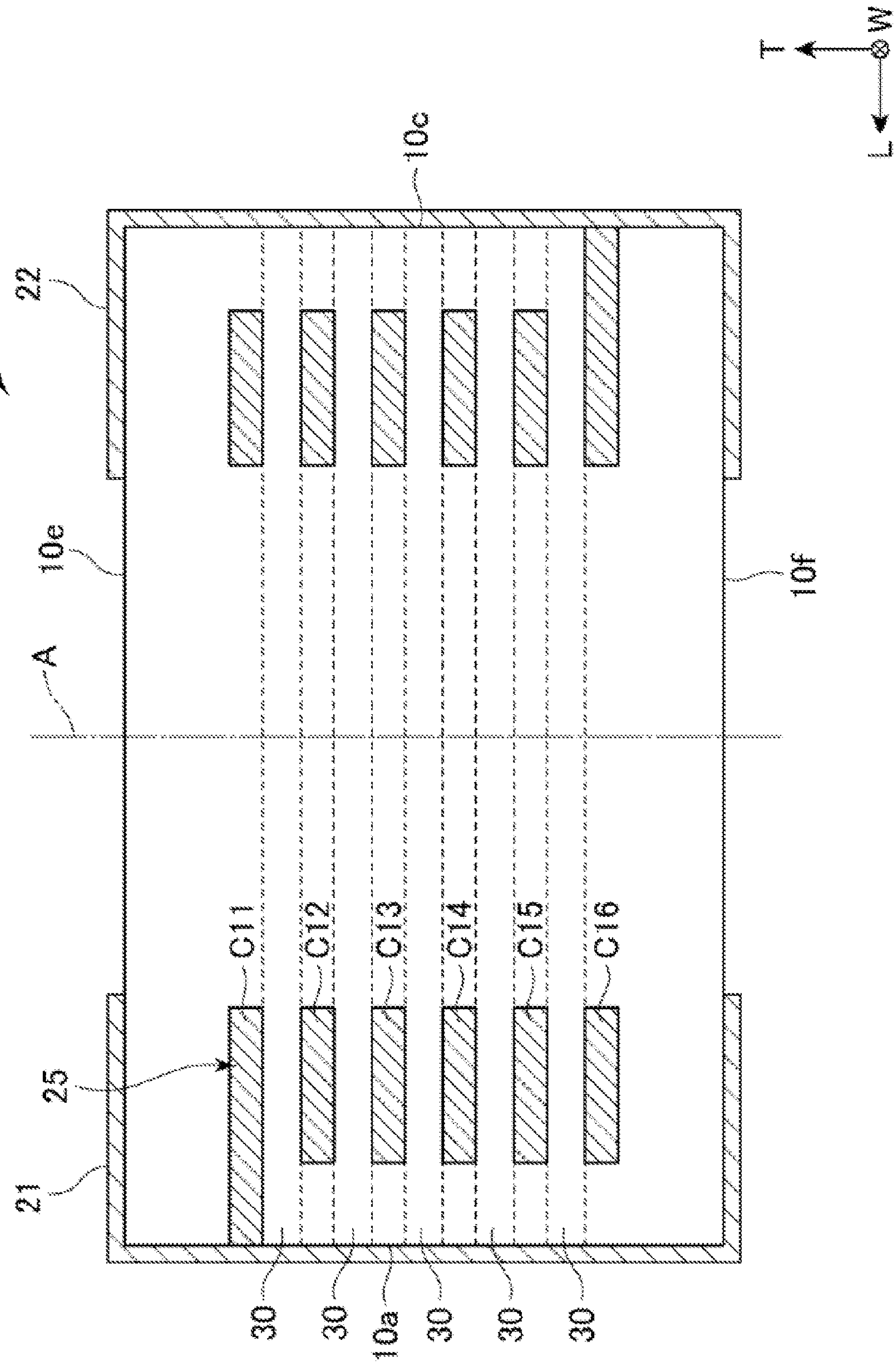


Fig. 4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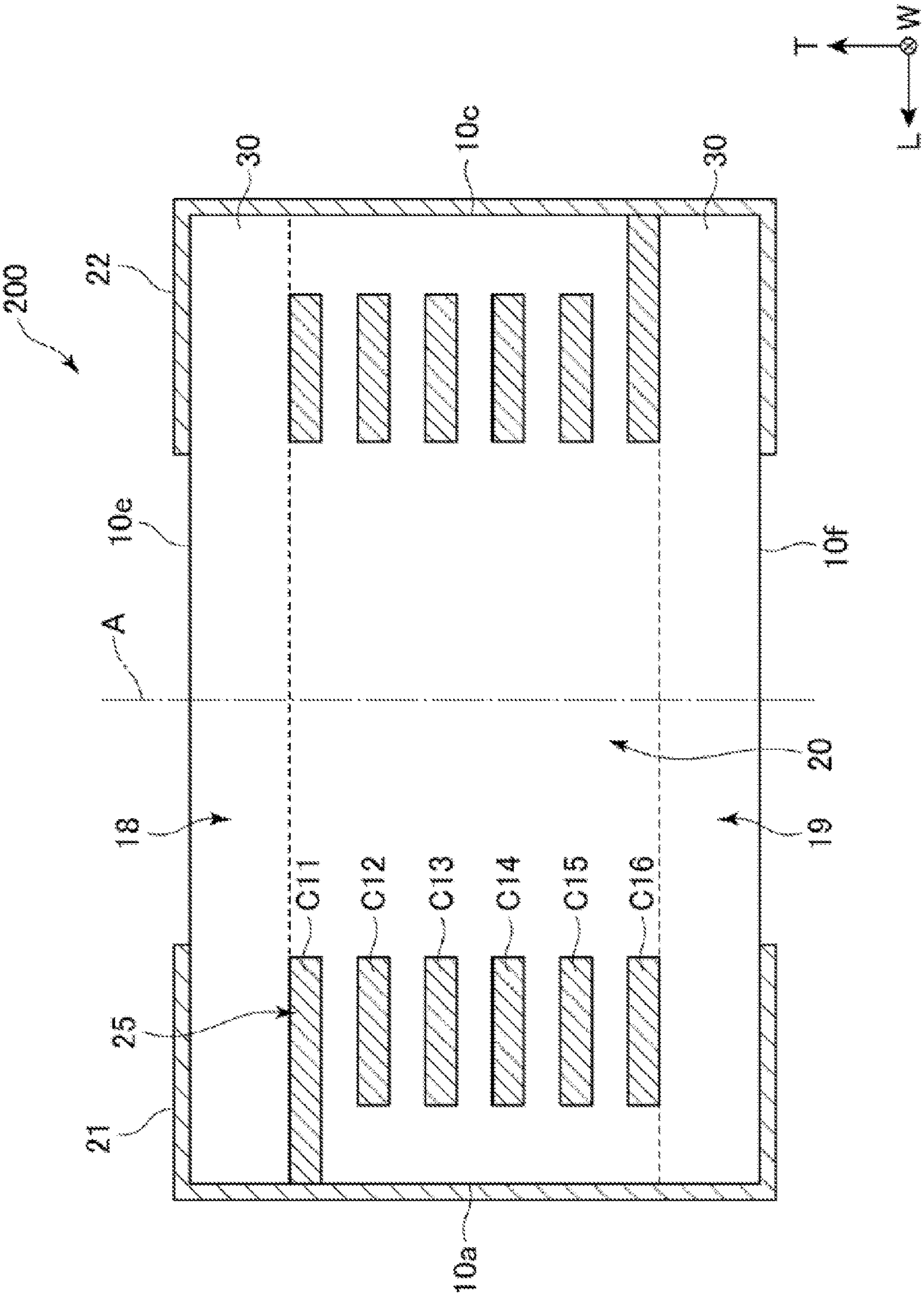
30
30

Fig. 5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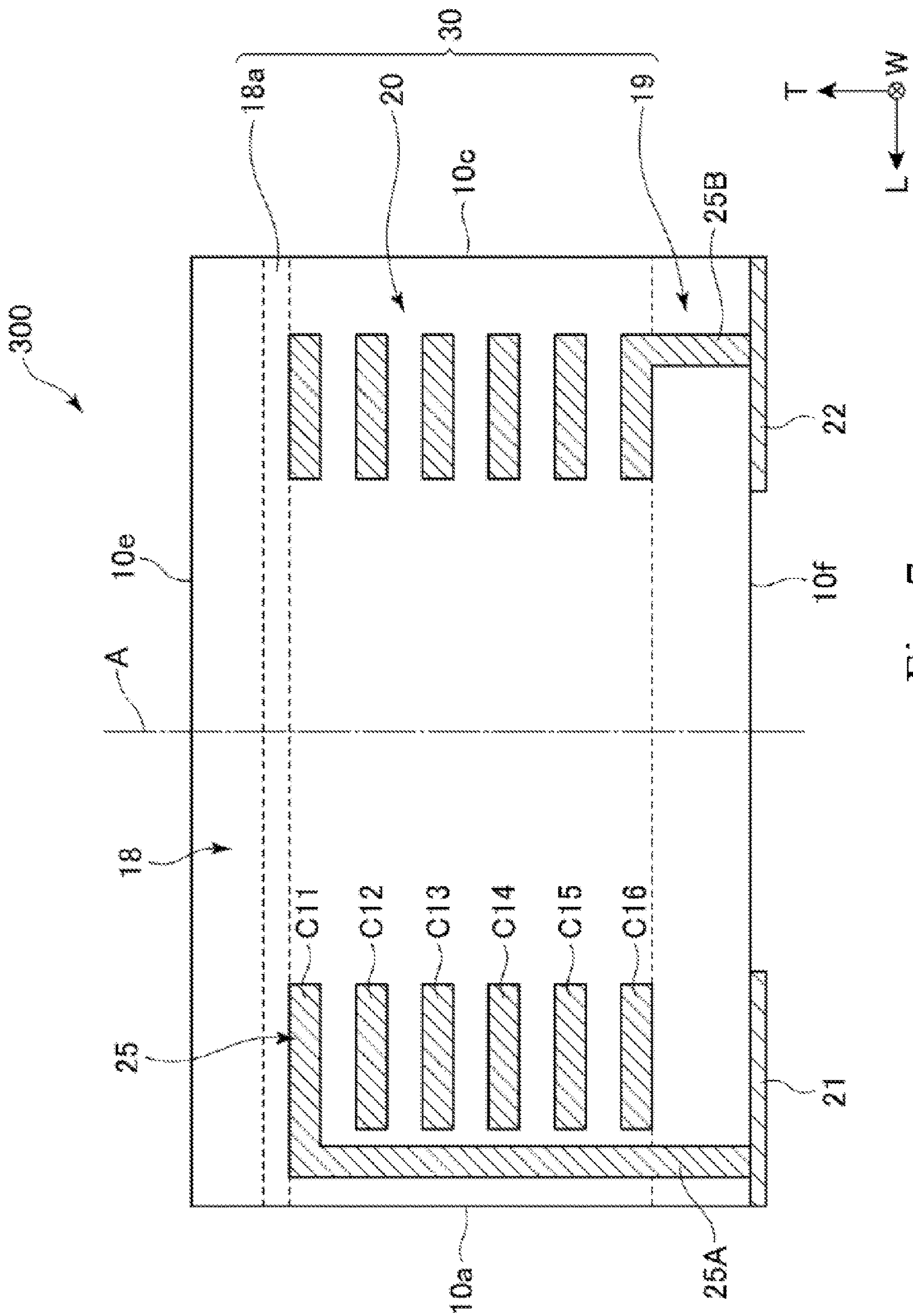
25
21
10a

Fig. 6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10e
10f
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C12
C13
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T
W
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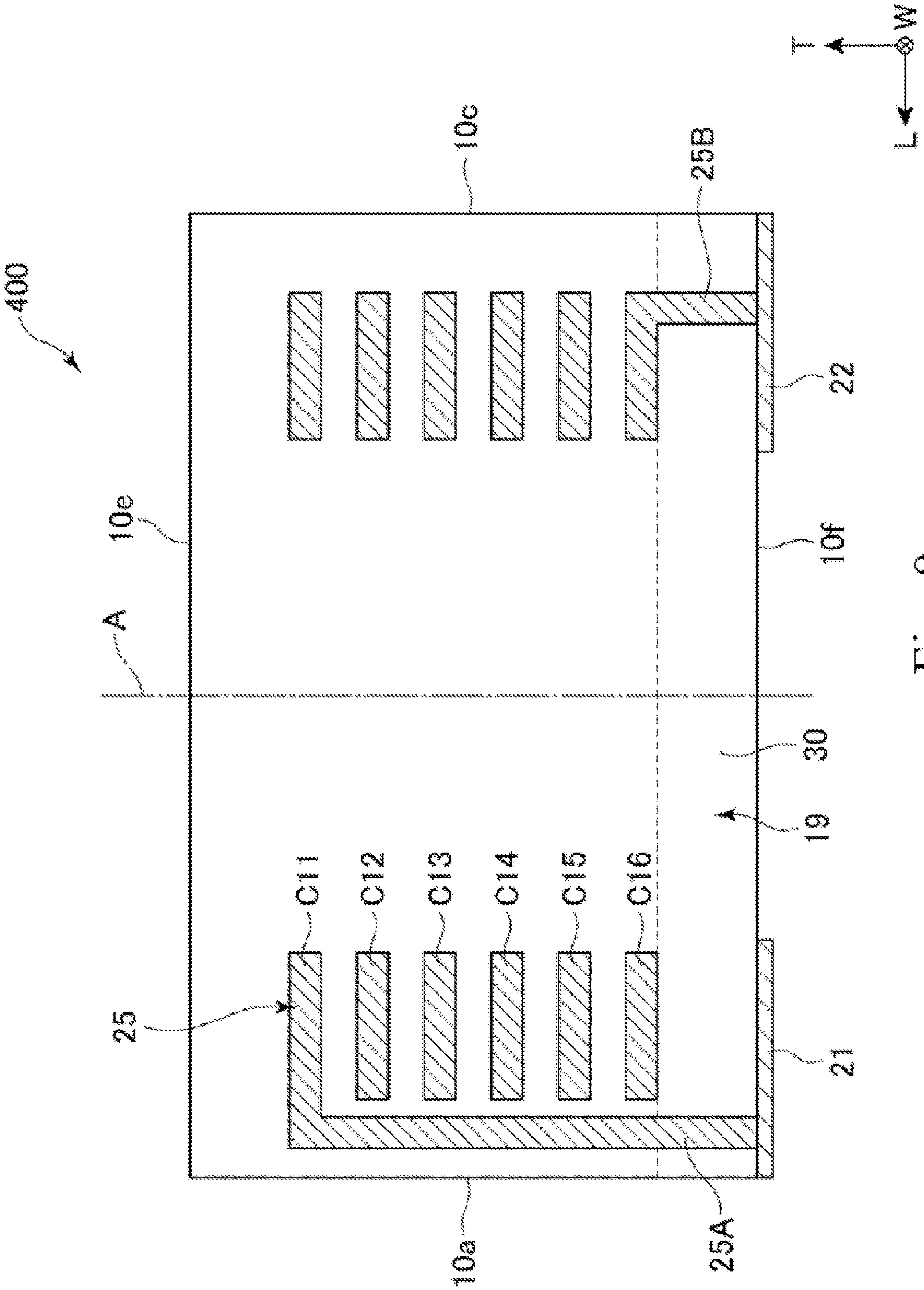
Fig. 7



400
10c
25B
T
W
L
10e
A
22
10f
30
19
C11
C12
C13
C14
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C16
25
21
10a
25A

Fig. 8

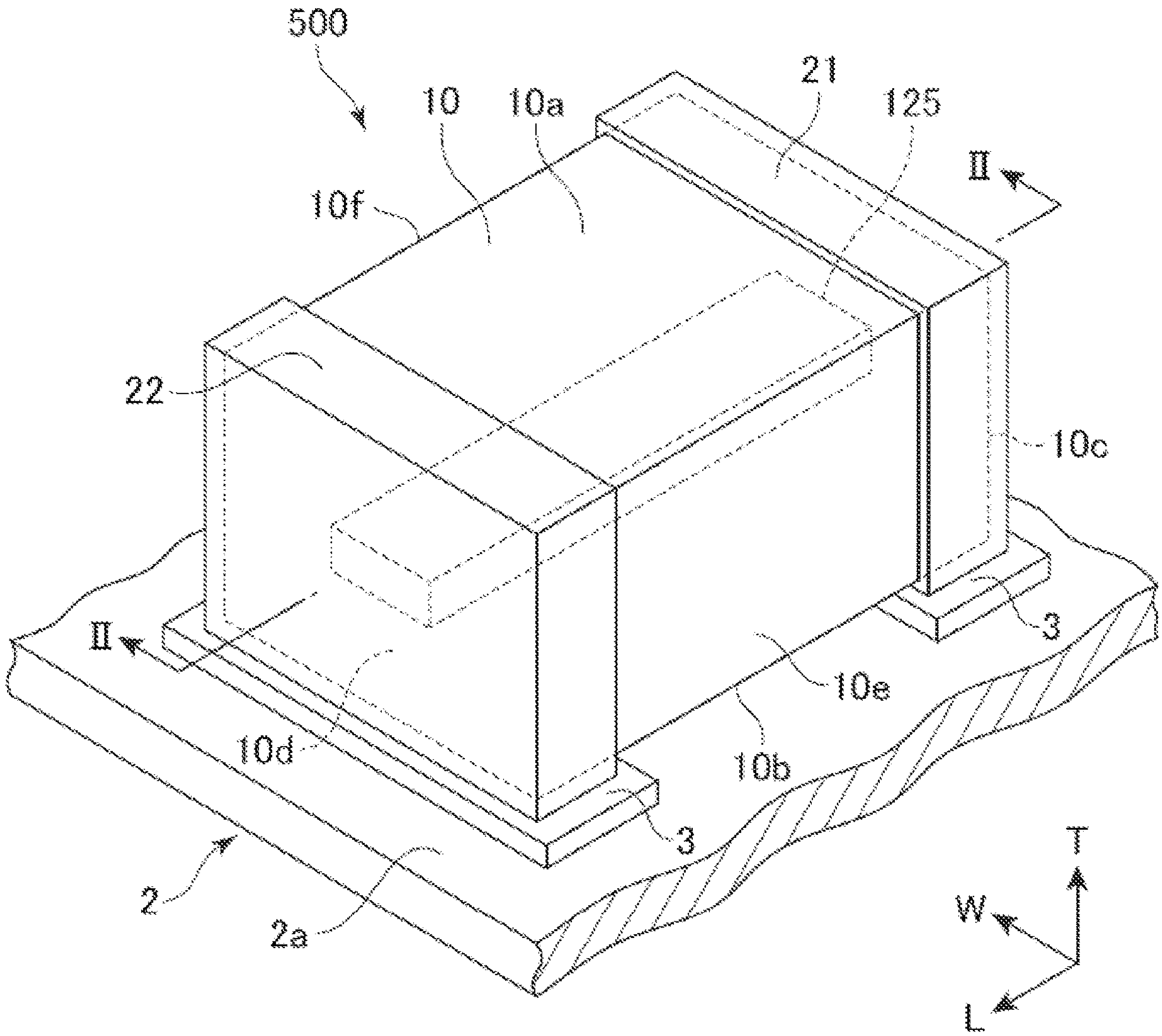

Fig. 9

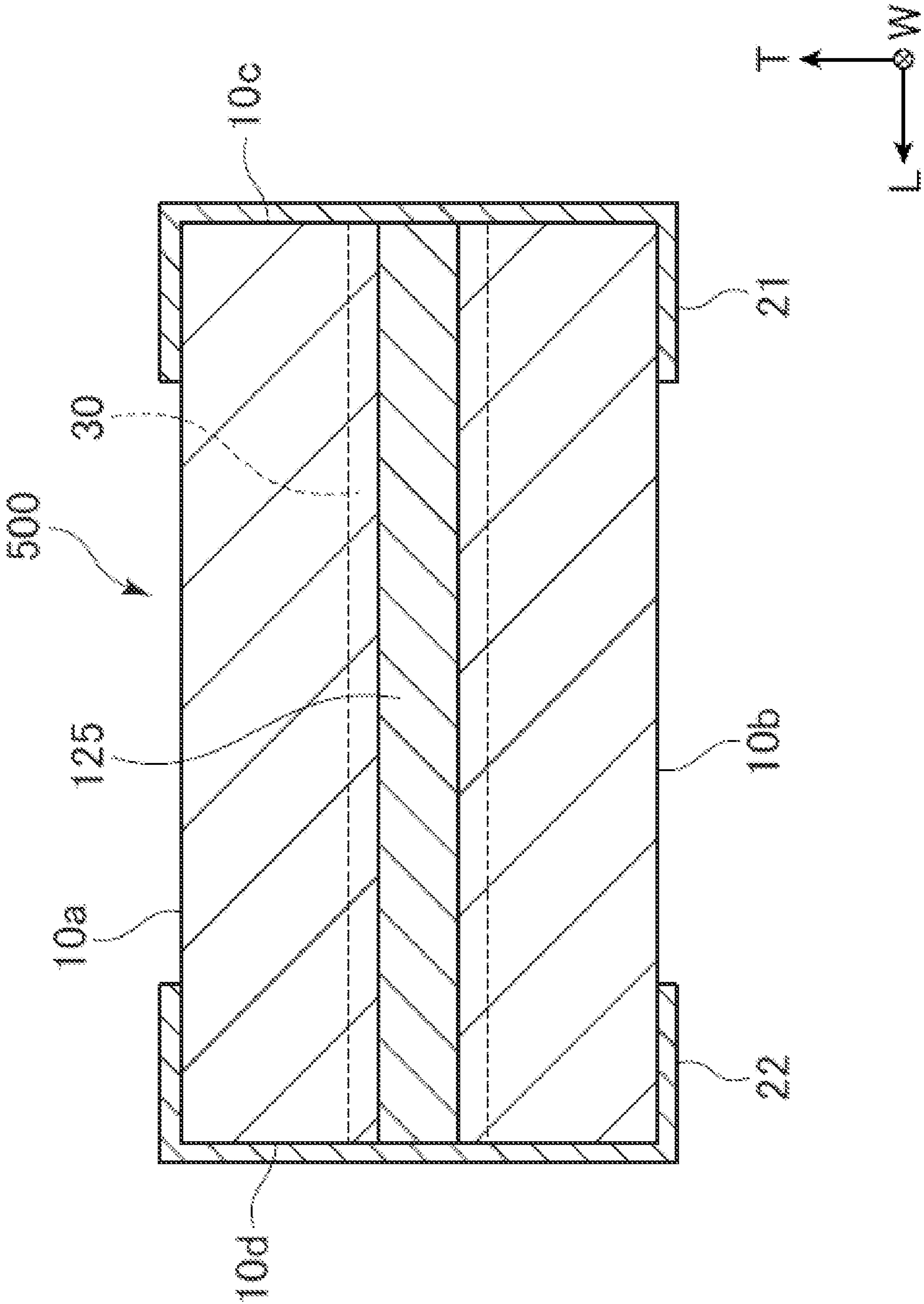

Fig. 10

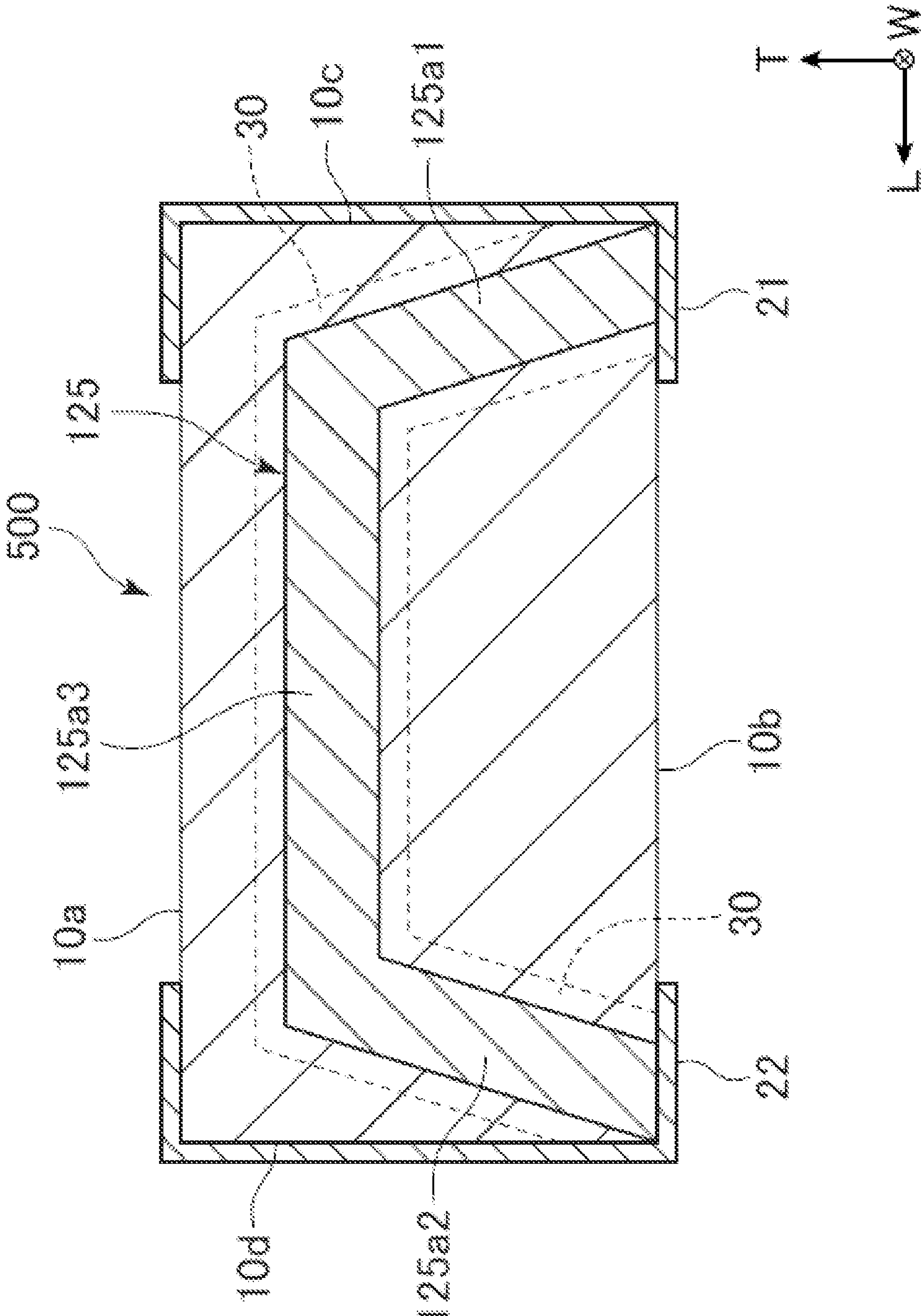

Fig. 11

COIL COMPONENT

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based on and claims the benefit of priority from Japanese Patent Application Serial No. 2020-064762 (filed on Mar. 31, 2020), Japanese Patent Application Serial No. 2020-149825 (filed on Sep. 7, 2020) and Japanese Patent Application Serial No. 2021-034789 (filed on Mar. 4, 2021) the contents of which are hereby incorporated by reference in their entirety.

TECHNICAL FIELD

The present disclosure relates to a coil component.

BACKGROUND

A conventional coil component such as an inductor typically includes a magnetic base body made of a magnetic material, a coil conductor provided in the magnetic base body and wound around a coil axis, and an external electrode connected to an end portion of the coil conductor. A known material of the magnetic base body is a metal magnetic material formed of metal magnetic particles. Metal magnetic materials typically have a higher saturation magnetic flux density than ferrite materials and thus are suitable as materials for a magnetic base body of a coil component through which a large current flows. An example of such a coil component made of a metal magnetic material is disclosed in Japanese Patent Application Publication No. 2018-121023.

The magnetic base body made of a metal magnetic material has a higher saturation magnetic flux density but a lower insulation quality than a magnetic base body made of a ferrite material. In addition, heat treatment in the manufacturing process of the coil component may cause migration of the metal atoms included in the conductor, such that the metal atoms of the coil conductor disperse into the magnetic base body. Such migration of the metal atoms of the coil conductor may further reduce the insulation quality of the magnetic base body made of the metal magnetic material.

SUMMARY

One object of the present invention is to provide a coil component less prone to migration of the metal atoms included in the coil conductor. Other objects of the present invention will be made apparent through the entire description in the specification.

A coil component according to one embodiment of the present invention comprises: a base body containing a plurality of metal magnetic particles; and a coil conductor provided in the base body so as to contact with the base body, wherein the base body has an insulating portion including a non-metal magnetic particle region defined by at least three of the plurality of metal magnetic particles in a sectional surface of the base body, and wherein in the insulating portion, an atomic percent of Si is highest among those of materials constituting the non-metal magnetic particle region other than oxygen. In one embodiment of the present invention, the coil conductor is wound around a coil axis.

In one embodiment of the present invention, at a geometric center of the non-metal magnetic particle region in a sectional surface thereof along the coil axis, an atomic percent of Si may be highest among those of the materials constituting the non-metal magnetic particle region other than oxygen. In one embodiment of the present invention, at a geometric center of the non-metal magnetic particle region in a sectional surface of the base body cut along a plane extending through the coil conductor, an atomic percent of Si may be highest among those of the materials constituting the non-metal magnetic particle region other than oxygen.

In one embodiment of the present invention, a surface of each of the plurality of metal magnetic particles may be coated with a coating layer containing Si, and a composition of a material of the coating layer may be different from a composition of the materials of the non-metal magnetic particle region at the geometric center.

In one embodiment of the present invention, the plurality of metal magnetic particles may be bonded to each other via the coating layer.

In one embodiment of the present invention, an atomic percent of Si in the non-metal magnetic particle region may be 50 at % to 95 at %.

In one embodiment of the present invention, the non-metal magnetic particle region may contain Fe, Cr, and/or Al.

In one embodiment of the present invention, the plurality of metal magnetic particles may be formed of an alloy containing Fe, Si, Cr, or Al.

In one embodiment of the present invention, the coil conductor may include a first conductor pattern and a second conductor pattern each extending along a planar direction perpendicular to the coil axis, and the first conductor pattern and the second conductor pattern may be separated from each other in a direction of the coil axis, and the insulating portion may be disposed between the first conductor pattern and the second conductor pattern.

In one embodiment of the present invention, the coil conductor may further comprise an external electrode provided on a surface of the base body and electrically connected to the coil conductor, and the insulating portion may be disposed between the coil conductor and the external electrode.

In one embodiment of the present invention, the coil conductor may be disposed in the insulating portion.

In one embodiment of the present invention, an entirety of the base body may be the insulating portion.

In one embodiment of the present invention, the insulating portion may be formed by heating a metal magnetic paste containing the plurality of metal magnetic particles and a silicon resin.

One embodiment of the present invention relates to a circuit board comprising any one of the above electronic components. One embodiment of the present invention relates to an electronic device comprising the above circuit board.

Advantageous Effects

The present invention provides a coil component less prone to migration of the metal atoms included in the coil conductor.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a coil component according to one embodiment of the present invention.

FIG. **2** is an exploded perspective view of the coil component shown in FIG. **1**.

FIG. **3** schematically shows a longitudinal section of the coil component along the line I-I in FIG. **1**.

FIG. **4** is an enlarged sectional view schematically showing a partial region of an insulating portion shown in FIG. **3**.

FIG. **5** schematically shows a longitudinal section of a coil component according to another embodiment of the present invention.

FIG. **6** schematically shows a longitudinal section of a coil component according to another embodiment of the present invention.

FIG. **7** schematically shows a longitudinal section of a coil component according to another embodiment of the present invention.

FIG. **8** schematically shows a longitudinal section of a coil component according to another embodiment of the present invention.

FIG. **9** is a perspective view of a coil component according to another embodiment of the present invention.

FIG. **10** schematically shows a longitudinal section of the coil component along the line II-II in FIG. **9**.

FIG. **11** schematically shows a modification of the coil conductor of FIG. **10**.

DESCRIPTION OF THE EMBODIMENTS

Various embodiments of the present invention will be hereinafter described with reference to the accompanying drawings. The constituents common to multiple drawings are denoted by the same reference signs throughout the drawings. For convenience of explanation, the drawings are not necessarily drawn to scale.

FIG. **1** is a perspective view of a coil component **1** according to one embodiment of the present invention, and FIG. **2** is an exploded perspective view of the coil component **1** shown in FIG. **1**. By way of one example of the coil component **1**, FIGS. **1** and **2** show a laminated inductor used as a passive element in various circuits. The laminated inductor is one example of a laminated coil component to which the present invention is applicable. The present invention is applicable to coil components other than the laminated inductor, such as those made by compression molding or thin film molding. The present invention is applicable to a power inductor incorporated in a power source line and to various other coil components.

The coil component **1** in the embodiment shown includes a laminated body (base body) **10** containing a plurality of metal magnetic particles, a coil conductor **25** disposed in the laminated body **10** and wound around a coil axis A, an external electrode **21** electrically connected to one end of the coil conductor **25**, and an external electrode **22** electrically connected to the other end of the coil conductor **25**. The laminated body **10** is a laminate of magnetic layers each made of a magnetic material. The coil conductor **25** includes conductor patterns C**11** to C**16**. The conductor patterns C**11** to C**16** extend along the planar direction perpendicular to the coil axis A and are separated from each other in the direction of the coil axis A. Each of the conductor patterns C**11** to C**16** is electrically connected to adjacent conductor patterns through the vias V**1** to V**5**. In this way, the coil conductor **25** is constituted by the conductor patterns C**11** to C**16** and the vias V**1** to V**5**. The conductor pattern C**11** is electrically connected to the external electrode **21**, and the conductor pattern C**16** is electrically connected to the external electrode **22**.

As shown, in one embodiment of the present invention, the laminated body **10** is formed in a rectangular parallelepiped shape, for example. The laminated body **10** has a first principal surface **10***e*, a second principal surface **10***f*, a first end surface **10***a*, a second end surface **10***c*, a first side surface **10***b*, and a second side surface **10***d*. The outer surface of the laminated body **10** is defined by these six surfaces. The first principal surface **10***e* and the second principal surface **10***f* are opposed to each other, the first end surface **10***a* and the second end surface **10***c* are opposed to each other, and the first side surface **10***b* and the second side surface **10***d* are opposed to each other. In a case where the laminated body **10** is formed in a rectangular parallelepiped shape, the first principal surface **10***e* and the second principal surface **10***f* are parallel to each other, the first end surface **10***a* and the second end surface **10***c* are parallel to each other, and the first side surface **10***b* and the second side surface **10***d* are parallel to each other.

In the embodiment of FIG. **1**, the first principal surface **10***e* lies on a top side of the laminated body **10**, and therefore it may be herein referred to as "the top surface." Similarly, the second principal surface **10***f* may be referred to as "the bottom surface." The coil component **1** is disposed such that the second principal surface **10***f* faces the circuit board (not shown), and therefore, the second principal surface **10***f* may be herein referred to as "the mounting surface." The top-bottom direction of the coil component **1** is based on the top-bottom direction in FIG. **1**.

In this specification, a "length" direction, a "width" direction, and a "thickness" direction of the coil component **1** are referred to as an "L axis" direction, a "W axis" direction, and a "T axis" direction in FIG. **1**, respectively, unless otherwise construed from the context. The L axis, the W axis, and the T axis are perpendicular to one another. The coil axis A extends in the T axis direction. The direction in which the plane including the W axis direction and the L axis direction extends is the planar direction.

In one embodiment of the present invention, the coil component **1** has a length (the dimension in the direction of the L axis) of 0.2 to 6.0 mm, a width (the dimension in the direction of the W axis) of 0.1 to 4.5 mm, and a thickness (the dimension in the direction of the T axis) of 0.1 to 4.0 mm. These dimensions are mere examples, and the coil component **1** to which the present invention is applicable can have any dimensions that conform to the purport of the present invention. In one embodiment, the coil component **1** has a low profile. For example, the coil component **1** has a width larger than the thickness thereof.

FIG. **2** is an exploded perspective view of the coil component **1** shown in FIG. **1**. In FIG. **2**, the external electrode **21** and the external electrode **22** are omitted for convenience of illustration. As shown in FIG. **2**, the laminated body **10** includes a body portion **20**, a top cover layer **18** provided on the top-side surface of the body portion **20**, and a bottom cover layer **19** provided on the bottom-side surface of the body portion **20**. The body portion, which includes the magnetic layers **11** to **16** stacked together, is formed of the top cover layer **18**, the magnetic layer **11**, the magnetic layer **12**, the magnetic layer **13**, the magnetic layer **14**, the magnetic layer **15**, the magnetic layer **16**, and the bottom cover layer **19** that are stacked in this order from the top to the bottom in FIG. **2**.

The top cover layer **18** includes four magnetic layers **18***a* to **18***d*. The top cover layer **18** includes the magnetic layer **18***a*, the magnetic layer **18***b*, the magnetic layer **18***c*, and the magnetic layer **18***d* that are stacked in this order from the bottom to the top in FIG. **2**.

The bottom cover layer **19** includes four magnetic layers **19***a* to **19***d*. The bottom cover layer **19** includes the magnetic layer **19***a*, the magnetic layer **19***b*, the magnetic layer **19***c*, and the magnetic layer **19***d* that are stacked in this order from the top to the bottom in FIG. **2**.

The magnetic layers **11** to **16** constituting the body portion **20**, the magnetic layers **18***a* to **18***d* constituting the top cover layer **18**, and the magnetic layers **19***a* to **19***d* constituting the bottom cover layer **19** include metal magnetic particles and an insulating resin material. Metal magnetic particles applicable to the present invention are made of a material in which magnetism is developed in an unoxidized metal portion, and such metal magnetic particles are, for example, particles including unoxidized metal particles or alloy particles. Magnetic particles applicable to the present invention include, for example, Fe and at least one of Al and Mn as an alloy component. Materials of the magnetic particles applicable to the present invention may be particles of, for example, a Fe—Si—Cr—Al, Fe—Si—Cr—Mn, Fe—Si—Al, Fe—Si—Mn, or Fe—Ni alloy, a Fe—Si—Cr—B—C or Fe—Si—B—Cr amorphous alloy, Fe, or a mixture thereof. The resin material contained in the magnetic layers will be described later.

The coil component **1** can include any number of magnetic layers as necessary in addition to the magnetic layers **11** to **16**, the magnetic layers **18***a* to **18***d*, and the magnetic layers **19***a* to **19***d*. Some of the magnetic layers **11** to **16**, the magnetic layers **18***a* to **18***d*, and the magnetic layers **19***a* to **19***d* can be omitted as appropriate.

The magnetic layers **11** to **16** have corresponding conductor patterns C**11** to C**16** embedded therein, respectively. Before the magnetic layers **11** to **16** are stacked together, the top-side surfaces of the conductor patterns C**11** to C**16** are exposed at the top-side surfaces of the magnetic layers **11** to **16**, respectively. The conductor patterns C**11** to C**16** extend around the coil axis A. In the embodiment shown, the coil axis A extends in the T axis direction, which is the same as the lamination direction of the magnetic layers **11** to **16**.

The magnetic layers **11** to **15** are provided with vias V**1** to V**5**, respectively, at predetermined locations therein. The vias V**1** to V**5** are formed by forming a through-hole at the predetermined location in the magnetic layers **11** to **15** so as to extend through the magnetic layers **11** to **15** in the Taxis direction and then filling the through-holes with a metal material.

The conductor patterns C**11** to C**16** and the vias V**1** to V**5** are formed to contain a metal having an excellent electrical conductivity, such as Ag, Pd, Cu, or Al, or any alloy of these metals.

In one embodiment, the external electrode **21** is provided on the first end surface **10***a* of the laminated body **10**, and the external electrode **22** is provided on the second end surface **10***c* of the laminated body **10**. As shown, the external electrode **21** and the external electrode **22** may extend onto the top surface **10***e*, the bottom surface **10***f*, the first side surface **10***b*, and the second side surface **10***d* of the laminated body **10**. In this case, the external electrode **21** covers the entirety of the first end surface **10***a* and a part of each of the top surface **10***e*, the bottom surface **10***f*, the first side surface **10***b*, and the second side surface **10***d* of the laminated body **10**, and the external electrode **22** covers the entirety of the second end surface **10***c* and a part of each of the top surface **10***e*, the bottom surface **10***f*, the first side surface **10***b*, and the second side surface **10***d* of the laminated body **10**. The shapes of the external electrode **21** and the external electrode **22** are not particularly limited and can be adjusted as appropriate. For example, the external electrode **21** may be L-shaped and cover a part of each of the first end surface **10***a* and the bottom surface **10***f*, or it may be plate-shaped and cover a part of the bottom surface **10***f*. Likewise, the external electrode **22** may be L-shaped and cover a part of each of the second end surface **10***c* and the bottom surface **10***f*, or it may be plate-shaped and cover a part of the bottom surface **10***f*.

Next, with reference to FIGS. **3** and **4**, a further description is given of the laminated body **10** of the coil component **1**. FIG. **3** schematically shows a longitudinal section of the coil component **1** along the line I-I in FIG. **1**. In FIG. **3**, a part of the magnetic layers included in the laminated body **10** is omitted. FIG. **4** is an enlarged sectional view schematically showing a partial region of an insulating portion **30** shown in FIG. **3**.

In one or more embodiments of the present invention, the laminated body **10** includes the insulating portion **30** that forms at least a part of the laminated body **10**. The laminated body **10** may be entirely formed of the insulating portion **30**. In the embodiment shown in FIG. **3**, the insulating portion **30** encloses the coil conductor **25**. In other words, in the coil component **1** shown, the coil conductor **25** is provided within the insulating portion **30**. The coil conductor **25** is provided in the laminated body **10** so as to contact with the insulating portion **30**. More specifically, in the embodiment shown, the insulating portion **30** includes the magnetic layers **11** to **16** constituting the body portion **20** (see FIG. **2**), the magnetic layer **18***a* of the top cover layer **18**, and the magnetic layer **19***a* of the bottom cover layer **19**.

The magnetic layers of the laminated body **10** are formed of a metal magnetic paste containing the metal magnetic particles and the insulating resin material. The metal magnetic paste used for the magnetic layers **11** to **16**, **18***a*, **19***a* constituting the insulating portion **30** contains a silicon resin as the resin material. The proportion of the silicon resin in the metal magnetic paste may be, for example, 5 vol % to 50 vol %. For the metal magnetic paste used for the magnetic layers not constituting the insulating portion **30** (the magnetic layers **18***b* to **18***d*, **19***b* to **19***d* in this embodiment), examples of the resin material contained in this metal magnetic paste include a polyvinyl butyral (PVB) resin, an ethyl cellulose resin, a polyvinyl alcohol resin, and an acrylic resin. The resin material used for the magnetic layers **18***b* to **18***d*, **19***b* to **19***d* not constituting the insulating portion **30** may be a highly insulating thermosetting resin. Examples of this thermosetting resin include an epoxy resin, a polyimide resin, a polystyrene (PS) resin, a high-density polyethylene (HDPE) resin, a polyoxymethylene (POM) resin, a polycarbonate (PC) resin, a polyvinylidene fluoride (PVDF) resin, a phenolic resin, a polytetrafluoroethylene (PTFE) resin, or a polybenzoxazole (PBO) resin.

As shown in FIG. **4**, the insulating portion **30** includes metal magnetic particle regions R**1** and non-metal magnetic particle regions R**2**. The metal magnetic particle regions R**1** are formed of a plurality of metal magnetic particles **31**, and the non-metal magnetic particle regions R**2** are each defined by at least three metal magnetic particles **31** in a sectional surface of the laminated body **10** along any direction. In the sectional surface of the laminated body **10**, the three metal magnetic particles **31** defining one non-metal magnetic particle region R**2** contact with each other. The non-metal magnetic particle regions R**2** may be each defined by four or more metal magnetic particles **31**. In the non-metal magnetic particle regions R**2**, the proportion of Si is the highest among those of the materials constituting the non-metal magnetic particle regions R**2** other than oxygen. The non-metal magnetic particle regions R**2** are filled with a Si oxide. The non-metal magnetic particle regions R**2** may contain, for example, Fe and/or Cr in addition to Si and oxygen. Of the materials constituting the non-metal magnetic particle regions R**2** other than oxygen, the proportion of Si is 50 at % to 95 at %, by way of one example.

The proportion of Si in each non-metal magnetic particle region R**2** is based on the geometric center C of the non-metal magnetic particle region R**2** as viewed in the sectional surface thereof along the coil axis A. At the geometric center C of the non-metal magnetic particle region R**2** as viewed in the sectional surface thereof along the coil axis A, the atomic percent of Si is the highest among those of the materials other than oxygen. The proportion of Si is measured by, for example, EDS (energy dispersive X-ray spectroscopy) analysis.

The surface of each metal magnetic particle **31** may be coated with a coating layer **32**. The coating layer **32** may be, for example, an oxide film formed of oxidized surface of the metal magnetic particle **31**, a coating film containing Si, or a coating film containing an element other than Si. The oxide film and the coating film may be insulating films. The metal magnetic particles **31** are bonded to each other via the coating layers **32**. When the coating layer **32** is formed on the surface of the metal magnetic particle **31**, the coating layer **32** is a part of the metal magnetic particle **31** and is included in the metal magnetic particle region R**1**. The composition of the material of the coating layer **32** may be different from the composition of the materials of the non-metal magnetic particle region R**2** at the geometric center C.

Next, a description is given of an example of a method of manufacturing the coil component **1**. The first step is to form a top laminate, an intermediate laminate, and a bottom laminate. The top laminate will constitute the top cover layer **18**, and the bottom laminate will constitute the bottom cover layer **19**. The top laminate is formed by stacking together a plurality of magnetic sheets that are to be the magnetic layers **18***a* to **18***d*. Likewise, the bottom laminate is formed by stacking together a plurality of magnetic sheets that are to be the magnetic layers **19***a* to **19***d*. These magnetic sheets are formed by, for example, applying a metal magnetic paste to a surface of a plastic base film, drying the metal magnetic paste, and cutting the dried metal magnetic paste to a predetermined size. The metal magnetic paste is formed of, for example, a resin material containing metal magnetic particles mixed with a solvent. The magnetic sheets to be the magnetic layers constituting the insulating portion **30** (the magnetic layers **11** to **16**, **18***a*, **19***a* in the embodiment shown) are formed using a silicon resin as the resin material. The resin material used in the magnetic sheets to be the magnetic layers not constituting the insulating portion **30** (the magnetic layers **18***b* to **18***d*, **19***b* to **19***d* in the embodiment shown) may be, for example, a polyvinyl butyral (PVB) resin, an epoxy resin, or any other resin materials having an excellent insulation quality.

The intermediate laminate is formed by stacking together a plurality of sheets each including a conductor pattern, a magnetic layer, and an insulator. In producing each sheet, a green sheet is first formed on a base film. The green sheet has a through-hole extending through the green sheet in the lamination direction and configured to receive a via formed therein. Next, the conductor pattern is formed on the green sheet by screen printing or any other method. At this time, the metal material that forms the conductor pattern is filled into the through-hole to form the via. The magnetic layer is then printed where the conductor pattern is not formed. After the sheets including the conductor patterns C**11** to C**16** are formed, the base film is removed, and the sheets are stacked together in the order from the sheet including the conductor pattern C**16** to the sheet including the conductor pattern C**11**. Since there is no conductor pattern below the conductor pattern C**16**, the sheet including the conductor pattern C**16** may not have a through-hole for forming the via.

Next, the intermediate laminate formed in the above-described manner is sandwiched between the top laminate on the top side and the bottom laminate on the bottom side, and the top laminate and the bottom laminate are bonded to the intermediate laminate by thermal compression to obtain a body laminate. Next, the body laminate is diced into pieces of a desired size using a cutter such as a dicing machine or a laser processing machine to obtain chip laminates corresponding to the laminated body **10**. Next, the chip laminate is degreased and then heated at a predetermined temperature. This heat treatment causes the silicon resin contained in the metal magnetic paste to be thermally decomposed into a Si oxide that is filled into the non-metal magnetic particle regions R**2** in the insulating portion **30**. When the metal magnetic particles contain at least one of Al and Mn as an alloy component, the heat treatment produces at least one of Al oxide and Mn oxide that fills the non-metal magnetic particle regions R**2** in the insulating portion **30**. In this way, the non-metal magnetic particle regions R**2** may contain the Si oxide and at least one of Al oxide and Mn oxide mixed together. Since the metal magnetic particles contain at least one of Al and Mn, the voids of the non-metal magnetic particle regions R**2** can be reduced as compared to the case where the metal magnetic particles do not contain Al or Mn. Further, since at least one of Al oxide and Mn oxide is present in the non-metal magnetic particle regions R**2**, adjacent metal magnetic particles can be bound firmly to each other to increase the mechanical strength of the base body **10**. Following the heat treatment, a conductive paste is applied to the both end portions of the chip laminate to form the external electrode **21** and the external electrode **22**. The coil component **1** is thus obtained.

Next, another embodiment of the invention will be described with reference to FIG. **5**. FIG. **5** is a sectional view of the coil component according to the other embodiment cut along the plane corresponding to the longitudinal section of the FIG. **3**. As shown in FIG. **5**, similarly to the coil component **1**, the coil component **100** according to the other embodiment of the present invention includes a laminated body **10** containing a plurality of metal magnetic particles, a coil conductor **25** disposed in the laminated body **10** and wound around a coil axis A, an external electrode **21** electrically connected to one end of the coil conductor **25**, and an external electrode **22** electrically connected to the other end of the coil conductor **25**. The coil component **100** differs from the coil component **1** in that the insulating portion **30** of the laminated body **10** is disposed only in interposing regions disposed between the conductor patterns C**11** to C**16** that are adjacent to each other in the direction of the coil axis A. The interposing regions extend over the entirety of the laminated body **10** in the planar direction along the L axis direction and the W axis direction.

Next, another embodiment of the invention will be described with reference to FIG. **6**. FIG. **6** is a sectional view of the coil component according to the other embodiment cut along the plane corresponding to the longitudinal section of the FIG. **3**. As shown in FIG. **6**, similarly to the coil component **1**, the coil component **200** according to the other embodiment of the present invention includes a laminated body **10** containing a plurality of metal magnetic particles, a coil conductor **25** disposed in the laminated body **10** and wound around a coil axis A, an external electrode **21** electrically connected to one end of the coil conductor **25**, and an external electrode **22** electrically connected to the other end of the coil conductor **25**. In the coil component **200**, the insulating portion **30** is disposed in a region between the conductor pattern C**11** and the top surface **10***e* of the laminated body **10** and a region between the conductor pattern C**16** and the bottom surface **10***f* of the laminated body **10** in the direction of the coil axis A. In other words, in the coil component **200**, the top cover layer **18** (magnetic layers **18***a* to **18***d*) and the bottom cover layer **19** (magnetic layers **19***a* to **19***d*) correspond to the insulating portion **30**.

Next, another embodiment of the invention will be described with reference to FIG. **7**. FIG. **7** is a sectional view of the coil component according to the other embodiment cut along the plane corresponding to the longitudinal section of the FIG. **3**. As shown in FIG. **7**, similarly to the coil component **1**, the coil component **300** according to the other embodiment of the present invention includes a laminated body **10** containing a plurality of metal magnetic particles, a coil conductor **25** disposed in the laminated body **10** and wound around a coil axis A, an external electrode **21** electrically connected to one end of the coil conductor **25**, and an external electrode **22** electrically connected to the other end of the coil conductor **25**. In the coil component **300**, the external electrodes **21**, **22** are provided only on the bottom surface **10***f* of the laminated body **10**. The coil conductor **25** additionally includes a lead-out conductor **25**A and a lead-out conductor **25**B. The lead-out conductor **25**A electrically connects between one end of the coil conductor **25** and the external electrode **21**, and the lead-out conductor **25**B electrically connects between the other end of the coil conductor **25** and the external electrode **22**. More specifically, the lead-out conductor **25**A leads from the conductor pattern C**11** along the direction of the coil axis A and connects to the external electrode **21**. The lead-out conductor **25**B leads from the conductor pattern C16 along the direction of the coil axis A and connects to the external electrode **22**. The insulating portion **30** of the coil component **300** covers the entirety of the coil conductor **25** (that is, the conductor patterns C**11** to C**16**, the vias V**1** to V**5**, and the lead-out conductors **25**A, **25**B). In other words, in the coil component **300**, the magnetic layers **11** to **16** included in the body portion **20**, the magnetic layers **18***a* included in the top cover layer **18**, and the magnetic layers **19***a* to **19***d* included in the bottom cover layer **19** correspond to the insulating portion **30**. In this way, the insulating portion **30** is present in the region where the conductor pattern C**16** faces the lead-out conductor **25**A and thus the potential difference is the largest. The insulating portion **30** is also present in the regions where the conductor patterns C**12** to C**15** and the vias V**1** to V**5** face the lead-out conductor **25**A and thus a potential difference is present, although the potential difference is smaller than that between the conductor pattern C**16** and the lead-out conductor **25**A.

Next, another embodiment of the invention will be described with reference to FIG. **8**. FIG. **8** is a sectional view of the coil component according to the other embodiment cut along the plane corresponding to the longitudinal section of the FIG. **3**. As shown in FIG. **8**, similarly to the coil component **300**, the coil component **400** according to the other embodiment of the present invention includes a laminated body **10** containing a plurality of metal magnetic particles, a coil conductor **25** disposed in the laminated body **10** and wound around a coil axis A, an external electrode **21** electrically connected to one end of the coil conductor **25**, and an external electrode **22** electrically connected to the other end of the coil conductor **25**. As in the coil component **300**, the external electrodes **21**, **22** of the coil component **400** are provided only on the bottom surface **10***f* of the laminated body **10**, and the coil conductor **25** additionally includes a lead-out conductor **25**A and a lead-out conductor **25**B. The lead-out conductor **25**A electrically connects between one end of the coil conductor **25** and the external electrode **21**, and the lead-out conductor **25**B electrically connects between the other end of the coil conductor **25** and the external electrode **22**. More specifically, the lead-out conductor **25**A leads from the conductor pattern C**11** along the direction of the coil axis A and connects to the external electrode **21**. The lead-out conductor **25**B leads from the conductor pattern C**16** along the direction of the coil axis A and connects to the external electrode **22**. In the coil component **400**, the insulating portion **30** is disposed in a region between the conductor pattern C**16** and the bottom surface **10***f* of the laminated body **10** in the direction of the coil axis A. In other words, in the coil component **400**, the bottom cover layer **19** (magnetic layers **19***a* to **19***d*) correspond to the insulating portion **30**. In this way, the insulating portion **30** is present in the region between the conductor pattern C**16** and the external electrode **21** where the potential difference is large.

Next, another embodiment of the invention will be described with reference to FIGS. **9** and **10**. FIG. **9** is a perspective view of the coil component according to the other embodiment of the invention. As shown in FIG. **9**, similarly to the coil component **1**, the coil component **500** according to the other embodiment of the invention includes a laminated body **10**, The coil component **500** also includes a coil conductor **125** disposed in the laminated body **10**, an external electrode **21** electrically connected to one end of the coil conductor **25**, and an external electrode **22** electrically connected to the other end of the coil conductor **25**.

The coil conductor **125** is positioned so as to be enclosed in the insulating portion **30** of the laminated body **10**. The coil conductor **125** is provided in the laminated body **10** so as to contact with the insulating portion **30**. The coil conductor **125** is exposed at one end thereof to the outside of the magnetic base body **10** through the first end surface **10***c* and is connected to the external electrode **21** at the one end. The coil conductor **125** is also exposed at the other end thereof to the outside of the magnetic base body **10** through the second end surface **10***d* and is connected to the external electrode **22** at the other end. In this manner, the coil conductor **125** is connected at one end thereof to the external electrode **21** and connected at the other end thereof to the external electrode **22**.

The coil conductor **125** extends linearly from the external electrode **21** to the external electrode **22** in plan view (as viewed from the T axis). Stated differently, the coil conductor **125** has no separate parts facing each other in the laminated body **10** in a plan view. Herein, when the coil conductor **125** has no separate parts facing each other in the laminated body **10** in a plan view, this can mean the coil conductor **125** extends linearly from the external electrode **21** to the external electrode **22**. In the embodiment shown, the coil conductor **125** has a rectangular parallelepiped shape. The coil conductor **125** may be formed by only a single conductor pattern or by a plurality of conductor patterns electrically insulated from each other in the laminated body **10**. When the coil conductor **125** is formed by a plurality of conductor patterns, these conductor patterns have the same shape, and adjacent ones of the conductor patterns are separated from each other by a part of the insulating portion **30** of the laminated body **10**.

In the embodiment shown in FIGS. **9** and **10**, the insulating portion **30** is also configured as shown in FIG. **4**.

Specifically, the insulating portion **30** includes metal magnetic particle regions R**1** and non-metal magnetic particle regions R**2**. The metal magnetic particle regions R**1** are formed of a plurality of metal magnetic particles **31**, and the non-metal magnetic particle regions R**2** are each defined by at least three metal magnetic particles **31** in a sectional surface of the laminated body **10** along any direction. In the non-metal magnetic particle regions R**2**, the proportion of Si is the highest among those of the materials constituting the non-metal magnetic particle regions R**2** other than oxygen. The proportion of Si in each non-metal magnetic particle region R**2** is based on the geometric center C of the non-metal magnetic particle region R**2** in the sectional surface thereof cut along a plane extending through the coil conductor **125** (for example, a plane extending through the coil conductor **125** and parallel with the LT plane). In other words, at the geometric center C of the non-metal magnetic particle region R**2** in the sectional surface thereof cut along a plane extending through the coil conductor **125**, the atomic percent of Si is the highest among those of the materials other than oxygen.

The shape of the coil conductor **125** is not limited to the illustrated. As shown in FIG. **11**, the coil conductor **125** may be configured such that the opposite ends thereof are exposed through the mounting surface **10***b* of the laminated body **10**. The coil conductor **125** shown in FIG. **11** includes a first portion **125***a***1**, a second portion **125***a***2**, and a third portion **125***a***3**. The first portion **125***a***1** is exposed at one end thereof through the mounting surface **10***b* and extends from the one end in the positive direction of the T axis and the positive direction of the L axis. The second portion **125***a***2** is exposed at one end thereof through the mounting surface **10***b* and extends from the one end in the positive direction of the T axis and the negative direction of the L axis. The third portion **125***a***3** connects between the top-side end of the first portion **125***a***1** and the top-side end of the second portion **125***a***2**. The bottom-side end of the first portion **125***a***1** is connected to the external electrode **21**, and the bottom-side end of the second portion **125***a***2** is connected to the external electrode **22**. In the embodiment shown, the third portion **25***a***3** extends in parallel with the top surface **10***a*.

In one or more embodiments of the present invention, the laminated body **10** of the coil component has the insulating portion **30** that includes the non-metal magnetic particle regions R**2** each defined by at least three metal magnetic particles **31**, and the atomic percent of Si is the highest among those of the materials constituting the non-metal magnetic particle regions R**2** other than oxygen. In conventional coil components, the resin contained in the metal magnetic paste is thermally decomposed into carbon dioxide and others by the heat treatment in the manufacturing process, and therefore, voids are formed in the regions each defined by a plurality of metal magnetic particles (corresponding to the non-metal magnetic particle regions R**2**). Presence of such voids encourages the metal magnetic particles to contact with oxygen and thus encourages oxidation of Fe, Si, Cr and the like contained in the metal magnetic particles. As a result, ionizable substances contained in the metal material of the coil conductor are encouraged to receive electrons, which may cause migration of the metal atoms in the coil conductor. By contrast, in the coil component **1** according to one embodiment of the present invention, the Si oxide is present in the non-metal magnetic particle regions R**2**, as described above. This is because a silicon resin is used as the resin contained in the metal magnetic paste and, when the silicon resin is thermally decomposed by the heat treatment, the Si component contained in the silicon resin remains after the thermal decomposition and oxidizes to form the Si oxide. Since the Si oxide is present in the non-metal magnetic particle regions R**2**, less voids are formed by the heat treatment, and thus the oxidation of Fe, Si, Cr and the like contained in the metal magnetic particles is inhibited. Therefore, the metal atoms of the coil conductor **25** can be inhibited from migrating by the heat treatment.

In one or more embodiments of the present invention, the migration of the metal atoms of the coil conductor **25** may occur when the metal atoms move in the non-metal magnetic particle regions R**2** by application of a voltage to the coil component **25**. In the coil component **1** according one embodiment of the present invention, it is inhibited that the voids are formed in the non-metal magnetic particle regions R**2** of the insulating portion **30**, and therefore, even after the coil component **1** is mounted on a circuit board, the metal atoms of the coil conductor **25** are inhibited from migrating by application of the voltage.

In one or more embodiments of the present invention, the coil conductor **25** is provided in the insulating portion **30**. With this arrangement, the migration of the metal materials of the coil conductor **25** can be inhibited between any two of the conductor patterns C**11** to C**16** of the coil conductor **25** and between the coil conductor **25** and the external electrodes **21**, **22**. Accordingly, it is more secure that short circuits are inhibited from occurring in the coil component **1**.

In one or more embodiments of the present invention, the insulating portion **30** is formed by heating a metal magnetic paste containing the metal magnetic particles **31** and the silicon resin. Since the silicon resin can be more easily fed into gaps between the metal magnetic particles **31** as compared to Si oxide particles, the filling factor of the Si oxide in the non-metal magnetic particle regions R**2** can be increased. Therefore, the metal atoms of the coil conductor **25** can be more effectively inhibited from migrating by the heat treatment.

In one or more embodiments of the present invention, the coil conductor **25** includes the conductor patterns C**11** to C**16** extending along the planar direction perpendicular to the coil axis A and separated from each other in the direction of the coil axis A, and the insulating portion **30** may be provided between adjacent ones of the conductor patterns C**11** to C**16**. With this arrangement, the migration of the metal materials of the coil conductor **25** can be inhibited between adjacent ones of the conductor patterns C**11** to C**16**.

In one or more embodiments of the present invention, the coil component further includes the external electrodes **21**, **22** provided on the surface of the laminated body **10** and electrically connected to the coil conductor **25**, and the insulating portion **30** may be provided between the coil conductor **25** and the external electrode **21**, **22**. With this arrangement, the migration of the metal materials of the coil conductor **25** can be inhibited between the coil conductor **25** and the external electrodes **21**, **22**.

In one or more embodiments of the present invention, the metal magnetic particles **31** may contain Al. With this arrangement, the metal magnetic particles **31** tends to have a thick coating layer **32**, and therefore, the gaps of the non-metal magnetic particle regions R**2** defined by the metal magnetic particles **31** are smaller. Accordingly, narrower paths are left for movement of the metal elements constituting the coil conductor **25** that are ionized, and thus the migration of the metal elements can be inhibited.

In one or more embodiments of the present invention, the metal magnetic particles **31** may contain Cr. Since Cr inhibits oxidation of Fe contained in the metal magnetic particles **31**, the metal elements of the coil conductor **25** can be inhibited from ionizing due to oxidation of Fe. Therefore, the metal materials of the coil conductor **25** can be inhibited from migrating.

The dimensions, materials, and arrangements of the constituent elements described for the above various embodiments are not limited to those explicitly described for the embodiments, and these constituent elements can be modified to have any dimensions, materials, and arrangements within the scope of the present invention. Furthermore, constituent elements not explicitly described herein can also be added to the above-described embodiments, and it is also possible to omit some of the constituent elements described for the embodiments.

For example, as to the various examples of the positions of the insulating portion **30** represented by the above embodiments, it is only required that the insulating portion **30** is provided in at least a part of the laminated body **10**, and the position of the insulating portion **30** is not limited to those in the above embodiments.

What is claimed is:

1. A coil component comprising:

a base body containing a plurality of metal magnetic particles; and

a coil conductor provided in the base body so as to contact with the base body and wound around a coil axis,

wherein the base body has an insulating portion, the insulating portion is disposed so as to surround at least a part of the coil conductor, the insulating portion including a non-metal magnetic particle region defined by at least three of the plurality of metal magnetic particles in a sectional surface of the base body, and

wherein at a geometric center of the non-metal magnetic particle region in a sectional surface thereof along the coil axis, an atomic percent of Si is highest among those of the materials constituting the non-metal magnetic particle region other than oxygen.

2. A coil component comprising:

a base body containing a plurality of metal magnetic particles; and

a coil conductor provided in the base body so as to contact with the base body,

wherein the base body has an insulating portion, the insulating portion is disposed so as to surround at least a part of the coil conductor, the insulating portion including a non-metal magnetic particle region defined by at least three of the plurality of metal magnetic particles in a sectional surface of the base body, and

wherein at a geometric center of the non-metal magnetic particle region in a sectional surface of the base body cut along a plane extending through the coil conductor, an atomic percent of Si is highest among those of the materials constituting the non-metal magnetic particle region other than oxygen.

3. The coil component of claim **1**,

wherein a surface of each of the plurality of metal magnetic particles is coated with a coating layer containing Si, and

wherein a composition of a material of the coating layer is different from a composition of the materials of the non-metal magnetic particle region at the geometric center.

4. The coil component of claim **3**, wherein the plurality of metal magnetic particles are bonded to each other via the coating layer.

5. The coil component of claim **1**, wherein an atomic percent of Si at the geometric center of the non-metal magnetic particle region is 50 at % to 95 at %.

6. The coil component of claim **1**, wherein the non-metal magnetic particle region contains Fe, Cr, and/or Al.

7. The coil component of claim **6**, wherein the plurality of metal magnetic particles are formed of an alloy containing Fe, Si, Cr, or Al.

8. The coil component of claim **1**, wherein the non-metal magnetic particle region contains at least one of Al and Mn.

9. The coil component of claim **1**, wherein the plurality of metal magnetic particles contain at least one of Al and Mn.

10. The coil component of claim **1**,

wherein the coil conductor includes a first conductor pattern and a second conductor pattern each extending along a planar direction perpendicular to the coil axis, and the first conductor pattern and the second conductor pattern are separated from each other in a direction of the coil axis, and

wherein the insulating portion of the base body is disposed between the first conductor pattern and the second conductor pattern.

11. The coil component of claim **1**, further comprising:

an external electrode provided on a surface of the base body and electrically connected to the coil conductor,

wherein the insulating portion is disposed between the coil conductor and the external electrode.

12. The coil component of claim **1**, wherein the coil conductor is disposed in the insulating portion.

13. The coil component of claim **1**, wherein an entirety of the base body is the insulating portion.

14. The coil component of claim **1**, wherein the insulating portion is formed by heating a metal magnetic paste containing the plurality of metal magnetic particles and a silicon resin.

15. A circuit board comprising the coil component of claim **1**.

16. An electronic component comprising the circuit board of claim **15**.

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